

APPLICATION
FOR
UNITED STATES LETTERS PATENT

TITLE: PORTING

APPLICANT: MARK R. HICKMAN, ANTONIO M. LAGE AND ROBERT
PRESTON PARKER

APPENDIX 2

CERTIFICATE OF MAILING BY EXPRESS MAIL

Express Mail Label No. EV 331 654 669 US

October 31, 2003
Date of Deposit



WebZIP New
Upgrad
Don't Show Ac

[Next](#) [Up](#) [Previous](#) [Contents](#)

Next: [Turbine Blades and Up: Wakes and Jets](#) Previous: [Wakes and Jets](#)

The Jet Pump

One practical use of the fluid jet is to pump fluids to a higher pressure by use of a jet of fluid injected into a pipe of moving fluid. Such a *jet pump* is illustrated in figure 5.6 which shows a jet of velocity V_j and area A_j aligned with the axis of a pipe of area A at a point where the pipe flow velocity is V_1 and the pressure is p_1 . At a distance downstream, where the two streams have completely mixed, the velocity is V_2 , and the pressure p_2 is greater than p_1 . The amount of the pressure rise $p_2 - p_1$ depends upon the velocities V_1 and V_j and the area ratio A_j/A in a manner that may be found by applying mass and momentum conservation to the fluid in the control volume shown in figure 5.6.

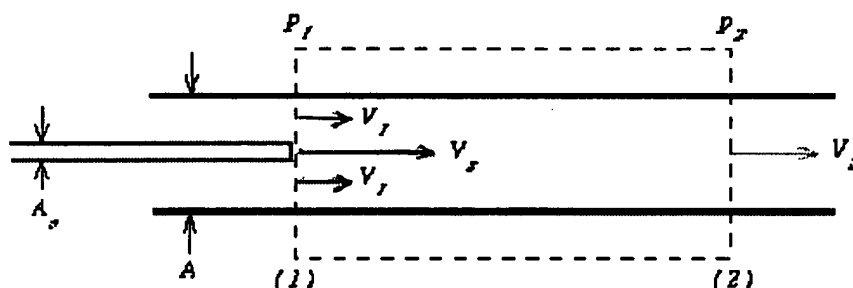


Figure 5.6: A jet pump consists of a coaxial jet of high speed fluid injected into a pipe of lower speed fluid. The mixing of the two streams produces a rise in pressure downstream.

We will consider the case for which the jet fluid and the pumped fluid are both incompressible and have the same density ρ . Applying mass conservation to the steady flow of fluid across the control surface of figure 5.6,

$$\rho A V_2 = \rho (A - A_j) V_1 + \rho A_j V_j$$

Next use the linear momentum equation 5.11 for the same control volume, but assume that the viscous force on the pipe walls is negligible ($\tau = 0$):

$$\begin{aligned}
& \frac{d}{dt} \iiint_V \rho \mathbf{V} dV + (\dot{m} \mathbf{V})_{\text{out}} - (\dot{m} \mathbf{V})_{\text{in}} \\
&= \iint_S (-p \mathbf{n}) dS + \iint_S dS + \iiint_V \rho \mathbf{g} dV + \Sigma \mathbf{F}_{\text{ex}} \\
& \quad 0 + \rho A V_2^2 - \rho(A - A_s) V_1^2 - \rho A_s V_s^2 \\
& \quad = (p_1 - p_2)A + 0 + 0 + 0
\end{aligned}$$

Eliminating V_2 between these two equations and solving for the pressure rise,

$$p_2 - p_1 = \frac{A_s}{A} \left(1 - \frac{A_s}{A} \right) \rho (V_s - V_1)^2 \quad (5.24)$$

The maximum pressure rise that we could expect would be that for inviscid flow of the jet decelerating from the speed V_s to $V_2 = V_s A_s / A$, or a pressure rise of $(\rho V_s^2 / 2)(1 - A_s^2 / A^2)$. Dividing equation 5.24 by this pressure rise, we have a dimensionless form of the jet pump equation:

$$\frac{p_1 - p_2}{\frac{1}{2} \rho V_s^2 \left[1 - (A_s / A)^2 \right]} = 2 \left(\frac{A_s / A}{1 + A_s / A} \right) \left(1 - \frac{V_1}{V_s} \right)^2 \quad (5.25)$$

Since $A_s / A \leq 1$ and $V_1 / V_s \leq 1$, the right side of equation 5.25 is always less than one.

The jet pump allows us to pump a greater volume flow rate ($V_1 [A - A_s]$) than that needed to supply the jet ($V_s A_s$), albeit with a lower pressure rise than that needed for the jet supply.

Example 5.12

A jet pump consists of a jet of diameter $D_j = 1$ in inside a pipe of diameter $D = 3$ in. The jet volumetric flow rate Q_j is 100 GPM (gallons per minute). Calculate the pressure rise in the jet pump when the volumetric flow rate Q_1 is 500 GPM.

Solution

In SI units, the flow areas and flow rates are:

$$A_j = \frac{\pi}{4}(2.54E(-2)\text{ m})^2 = 5.067E(-4)\text{ m}^2; \quad A = 9A_j = 4.560E(-3)\text{ m}^2$$

$$Q_j = \frac{100\text{ gal}}{\text{min}} \times \frac{3.785E(-3)\text{ m}^3}{\text{gal}} \times \frac{\text{min}}{60\text{ s}} = 6.308E(-3)\text{ m}^3/\text{s};$$

$$Q_1 = 5Q_j = 3.154E(-2)\text{ m}^3/\text{s}$$

and the velocities V_1 and V_j are:

$$V_1 = \frac{Q_1}{A - A_j} = \frac{3.154E(-2)\text{ m}^3/\text{s}}{4.560E(-3)\text{ m}^2 - 5.067E(-4)\text{ m}^2} = 7.781\text{ m/s}$$

$$V_j = \frac{Q_j}{A_j} = \frac{6.308E(-3)\text{ m}^3/\text{s}}{5.067E(-4)\text{ m}^2} = 12.45\text{ m/s}$$

Substituting these values in equation 5.24,

$$p_2 - p_1 = \frac{1}{9} \left(1 - \frac{1}{9} \right) (1E(3)\text{ kg/m}^3)(12.45\text{ m/s} - 7.781\text{ m/s})^2 = 2.153E(3)\text{ Pa}$$

[Next](#) [Up](#) [Previous](#) [Contents](#)

Next: [Turbine Blades and Up: Wakes and Jets](#) **Previous:** [Wakes and Jets](#)

Marie Hwang

Fri Mar 1 16:42:21 EST 1996